ESTIMATING CROP WATER USE

Estimates of crop water use are based on observed evaporation and the previously established relationship between evaporation and measured ET for specific crops at specific stages of development. This concept is expressed in the equation:

$$ET = Ep \times Kp$$

Where ET = crop water use (evapotranspiration)

Ep = evaporation from a U.S. Weather Bureau Class "A" pan located in a standardized (irrigated pasture) environment

Kp = crop coefficient for a specific crop at a specific stage of development

Generally, both evaporation (Ep) and crop coefficients (Kp) change with time throughout the growing season.

Selection of Crops

Table 1 lists crops grown in the southern San Joaquin Valley by both planted acres and percentage of the total planted acres. Initially, six crops comprising about 85 percent of the total planted land were selected for water use calculation. Because of marked differences in water use rates, deciduous orchard was separated into two categories: those with cover crop and those that were clean-cultivated. Since there was local interest in the water use rate of grain sorghum (milo), that crop was also included. In 1986 grain sorghum was replaced by another field crop – dry beans. Figures 2 and 3 show annual variations in acreage for the selected crops.

Development of Crop Coefficients (Kp's)

Monthly coefficients relating crop ET to observed evaporation from a USWB Class "A" pan were previously developed from DWR evapotranspiration field measurements for seven of the eight crop categories selected.[1] Coefficients for deciduous orchard with cover crop were based on other published data.[2]

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[1]Table 2A, Bulletin 113-3, *Vegetative Water Use in California*, Department of Water Resources, April 1975, p 38.

[2]Table 27, United Nations Food and Agriculture Organization, Irrigation and Drainage Paper No. 24, *Crop Water Requirements*, United Nations, Rome, 1977, p 77.

TABLE 1

RANKING OF IRRIGATED CROPS BY ACRES PLANTED AND PERCENTAGE OF TOTAL SOUTHERN SAN JOAQUIN VALLEY

Rank	Crop	Acres Planted[1,2] (1,000's)	Accumulated Acres Planted[1,2] (1,000's)	Percentage of Total Planted Acres	Accumulated Percentage of Total Planted Acres
1	Cotton	613.2	613.2	39.1	39.1
2	Deciduous orchard	177.5	790.7	11.3	50.4
3	Small grains	175.1	965.8	11.2	61.6
4	Alfalfa hay	163.8	1,129.6	10.4	72.0
5	Vineyard	148.9	1,278.5	9.5	81.5
6	Citrus and subtropical	77.0	1,355.5	4.9	86.4
7	Field corn	44.7	1,400.2	2.8	89.2
8	Safflower	39.5	1,439.7	2.5	91.7
9	Miscellaneous truck	33.1	1,472.8	2.1	93.8
10	Potatoes	18.5	1,491.3	1.2	95.0
11	Alfalfa seed	15.2	1,506.5	1.0	96.0
12	Sugar beets	12.5	1,519.0	0.8	96.8
13	Pasture	12.2	1,531.2	0.8	97.6
14	Dry beans	10.7	1,541.9	0.7	98.3
15	Grain sorghum	7.1	1,549.0	0.5	98.8
16	Melons	5.9	1,554.9	0.4	99.2
17	Tomatoes	5.0	1,559.9	0.3	99.5
18	Nursery	4.4	1,564.3	0.3	99.8
19	Miscellaneous field	3.9	1,568.2	0.2	100.0
20	Rice	0.5	1,568.7	0.0	100.0
Total		1,568.7		100.0	

[1]Includes double-cropped land; excludes fallow land.
[2]Based upon most recent Department of Water Resources land use survey: Kern County, 1990; Kings County, 1988; and Tulare County, 1985.

Since monthly Kp's are not suitable for estimating crop water use for short time periods, weekly Kp's were determined from smoothed curves fitted to the monthly values. This work was completed by Dr. Elias Fereres, UCCE Statewide Irrigation Specialist, and his staff. The weekly coefficients were consistently rounded to higher values. Thus, ET rates estimated from those coefficients are slightly higher than those based upon the original monthly crop coefficients.[1]

[1]Table 2A, Bulletin 113-3, *Vegetative Water Use in California*, Department of Water Resources, April 1975, p 38.

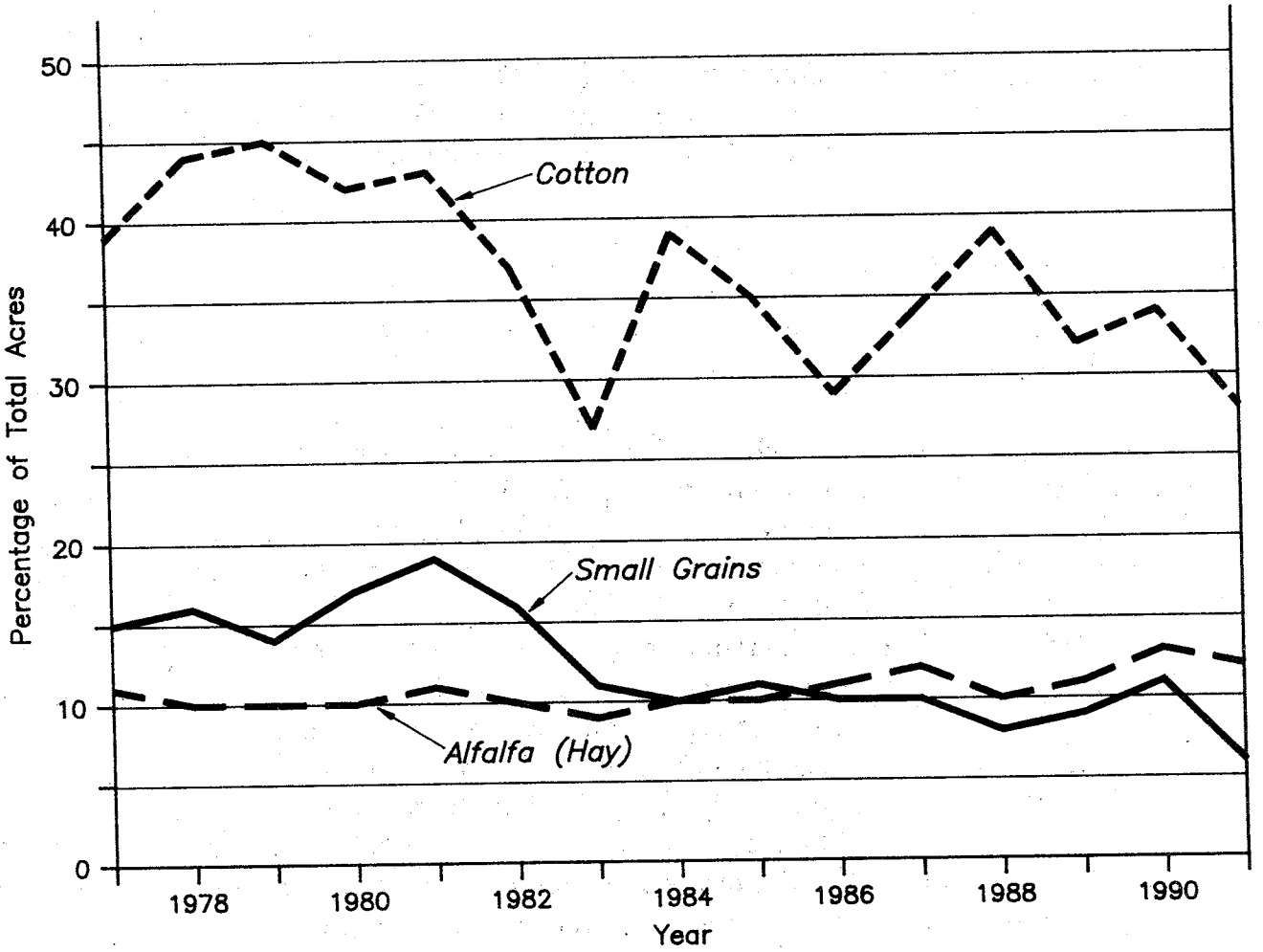


Figure 2. Land Planted to Major Field Crops, Southern San Joaquin Valley, 1977 to 1991

Note: Data Tabulated from Agricultual Commissioner's Annual Crop Reports for Kern, Kings, and Tulare Counties.

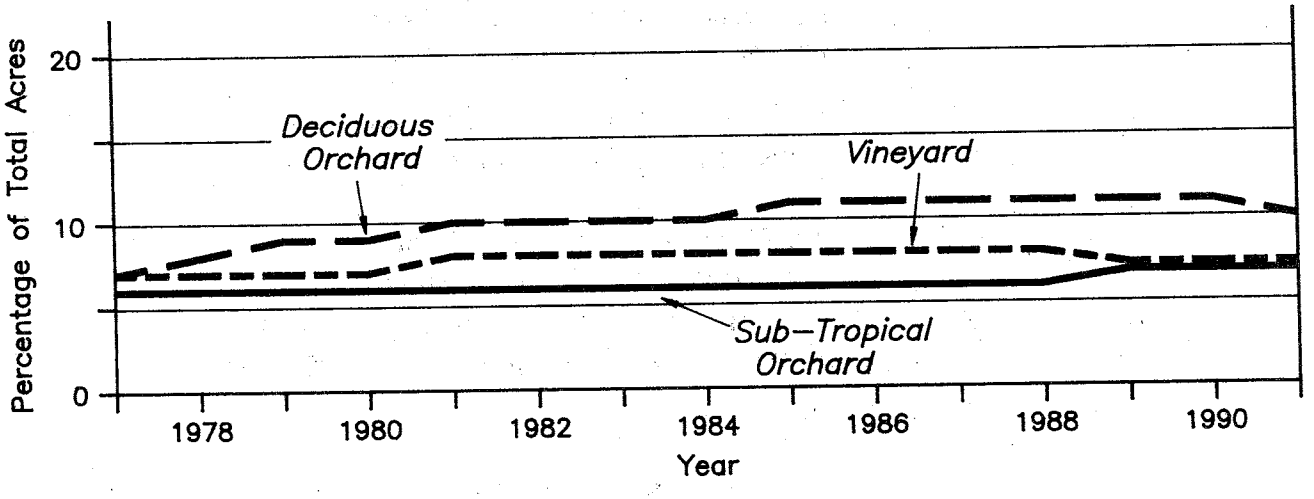


Figure 3. Land Planted to Trees and Vines, Southern San Joaquin Valley, 1977 to 1991

Note: Data Tabulated from Agricultual Commissioner's Annual Crop Reports for Kern, Kings, and Tulare Counties.

The weekly Kp's are presented in Table 2. These Kp's are for typical growing periods (planting and harvesting dates) for a normal year. They were adjusted as necessary to correspond to actual plant and harvest dates for each specific year.

Observed Evaporation Rates (Ep's)

Evaporation from Class "A" pans was observed at DWR agroclimatic stations in the Bakersfield area.

From January 1977 to December 1980, observations of evaporation were made each week at the Wasco 8SW agroclimatic station. This station was centrally located within the southern San Joaquin Valley (see Figure 1) and had the prescribed irrigated pasture environment. Evaporation rates observed at this location are believed to be representative of evaporation throughout the area. To assure that those evaporation rates were reliable, they were compared to evaporation measured at the U.S. Department of Agriculture's Cotton Research Station each week. The cotton station is located about 9 miles east of Wasco 8SW (Figure 1). Because of differing pan environments, long-term average evaporation at the cotton station is about 25 to 30 percent higher than that for a pan located in a large irrigated pasture (see Figure 4). Further, the relationship between Ep measured at the cotton station and Ep measured from a pan located in a pasture was not constant; it varied from year to year. Monthly evaporation observed at the cotton station and at the Wasco 8SW pasture station was highly correlated for each year, but the relationship was different for each year. The relationships between the two stations were:

Year	Relationship	Correlation Coefficient, "r"
1977	Ep cotton station = 0.04 + 1.231 Ep Wasco 8SW	0.99
1978	Ep cotton station = 0.11 + 1.287 Ep Wasco 8SW	0.98
1979	Ep cotton station = -0.57 + 1.272 Ep Wasco 8SW	0.97
1980	Ep cotton station = -0.04 + 1.189 Ep Wasco 8SW	0.98

The different annual relationships between the two locations are probably attributable to differences in cropping patterns adjacent to the cotton station pan.

Since the pasture in which the Wasco 8SW agroclimatic station was located was planned to be rotated to annual crops during 1981, a new station – Bakersfield 10NW – was established in late October 1980. Bakersfield 10NW was located approximately 18 miles east and 2 miles south of the Wasco 8SW site and about 9 miles east and 2 miles south of the USDA Cotton Research Station (Figure 1).

Wasco 8SW was removed in June 1981, when the pasture was plowed under. For the seven-month period of overlapping record (November 1980 through May 1981), evaporation at Bakersfield 10NW was in good agreement with evaporation measured at the Wasco site. This close relationship is shown in Figure 5.

TABLE 2

COEFFICIENTS (Kp) TO CALCULATE
WEEKLY CROP ET FROM PAN EVAPORATION (Ep)
FOR SEVERAL CROPS IN THE
SOUTHERN SAN JOAQUIN VALLEY[1]

Week Ending	Day of Year	Crop and Growing Season										
							Deciduous Orchard					
		ETP[2]	PET[3]	Alfalfa	Cotton	Citrus	No Cover Crop	w/Cover Crop	Grain Sorghum	Dry Beans	Small Grains	Vineyard
		Jan 1-Dec 31	Jan 1-Dec 31	Jan 1-Dec 31	Apr 15-Oct 4	Jan 1-Dec 31	Mar 4-Nov 25	Jan 1-Dec 31	Jun 17-Oct 21	May 13-Aug 26	Dec 2-Jun 3	Mar 18-Nov 25
Jan 7	7	0.92	0.71	0.76		0.60		0.71			0.30	
14	14	0.92	0.71	0.76		0.60		0.71			0.36	
21	21	0.92	0.72	0.76		0.60		0.72			0.43	
28	28	0.92	0.73	0.76		0.60		0.73			0.52	
Feb 4	35	0.92	0.74	0.76		0.60		0.74			0.62	
11	42	0.92	0.74	0.76		0.59		0.75			0.70	
18	49	0.92	0.75	0.76		0.59		0.75			0.78	
25	56	0.92	0.75	0.76		0.58		0.75			0.84	
Mar 4	63	0.92	0.76	0.76		0.58		0.76			0.89	
11	70	0.92	0.76	0.76		0.57	0.41	0.78			0.94	
18	77	0.92	0.77	0.76		0.56	0.44	0.80			0.96	
25	84	0.92	0.77	0.76		0.56	0.46	0.81			0.98	0.10
Apr 1	91	0.92	0.77	0.76		0.56	0.49	0.83			0.98	0.11
8	98	0.92	0.77	0.76		0.56	0.51	0.84			0.97	0.13
15	105	0.92	0.78	0.76		0.56	0.53	0.86			0.95	0.18
22	112	0.92	0.78	0.76	0.09	0.56	0.56	0.87			0.94	0.32
29	119	0.92	0.78	0.76	0.10	0.56	0.58	0.89			0.92	0.40
May 6	126	0.92	0.78	0.76	0.13	0.56	0.60	0.90			0.87	0.46
13	133	0.92	0.78	0.76	0.16	0.56	0.63	0.91			0.78	0.50
20	140	0.92	0.78	0.76	0.20	0.56	0.65	0.92		0.10	0.67	0.54
27	147	0.92	0.78	0.76	0.24	0.55	0.67	0.93		0.15	0.54	0.57
Jun 3	154	0.92	0.78	0.76	0.33	0.54	0.68	0.93		0.25	0.41	0.60
10	161	0.92	0.78	0.76	0.46	0.53	0.69	0.94		0.60		0.63
17	168	0.92	0.78	0.76	0.59	0.52	0.71	0.94		0.85		0.65
24	175	0.92	0.78	0.76	0.71	0.52	0.73	0.94	0.10	0.85		0.66
Jul 1	182	0.92	0.78	0.76	0.82	0.52	0.74	0.94	0.11	0.90		0.66
8	189	0.92	0.78	0.76	0.94	0.52	0.75	0.94	0.14	0.90		0.66
15	196	0.92	0.78	0.76	0.98	0.52	0.75	0.95	0.17	0.90		0.66
22	203	0.92	0.78	0.76	1.00	0.52	0.75	0.95	0.25	0.90		0.66
29	210	0.92	0.78	0.76	1.00	0.52	0.75	0.94	0.43	0.90		0.66
Aug 5	217	0.92	0.78	0.76	1.00	0.52	0.75	0.94	0.79	0.80		0.66
12	224	0.92	0.78	0.76	1.00	0.52	0.75	0.94	0.90	0.60		0.66
19	231	0.92	0.78	0.76	0.99	0.52	0.75	0.93	0.91	0.50		0.64
26	238	0.92	0.78	0.76	0.97	0.52	0.75	0.92	0.91	0.25		0.61
Sep 2	245	0.92	0.78	0.76	0.92	0.52	0.75	0.91	0.90			0.53
9	252	0.92	0.78	0.76	0.85	0.52	0.74	0.90	0.88			0.49
16	259	0.92	0.78	0.76	0.76	0.52	0.72	0.89	0.86			0.42
23	266	0.92	0.77	0.76	0.65	0.52	0.70	0.88	0.81			0.36
30	273	0.92	0.77	0.76	0.55	0.53	0.67	0.86	0.73			0.30
Oct 7	280	0.92	0.77	0.76	0.45	0.55	0.65	0.84	0.64			0.20
14	287	0.92	0.76	0.76	0.36	0.56	0.62	0.83	0.53			0.20
21	294	0.92	0.75	0.76		0.56	0.59	0.80	0.40			0.20
28	301	0.92	0.75	0.76		0.56	0.56	0.80				0.20
Nov 4	308	0.92	0.75	0.76		0.56	0.52	0.78				0.20
11	315	0.92	0.74	0.76		0.56	0.47	0.76				0.20
18	322	0.92	0.73	0.76		0.56	0.43	0.74				0.20
25	329	0.92	0.73	0.76		0.56	0.40	0.73				0.20
Dec 2	336	0.92	0.72	0.76		0.56		0.72				
9	343	0.92	0.71	0.76		0.56		0.71			0.18	
16	350	0.92	0.71	0.76		0.56		0.71			0.20	
23	357	0.92	0.70	0.76		0.56		0.70			0.22	
30	364	0.92	0.70	0.76		0.58					0.26	

[1]ET = (Kp) (Ep).

[2]Potential ET – alfalfa. ET of vigorously growing alfalfa at 100-percent ground cover with no moisture stress (Jensen-Haise alfalfa reference crop). Estimated as 0.92 x Ep throughout the year.

[3]Potential ET – grass. ET of large expanse of low-growing grass crop at 100-percent ground cover with no moisture stress (Penman grass reference crop).

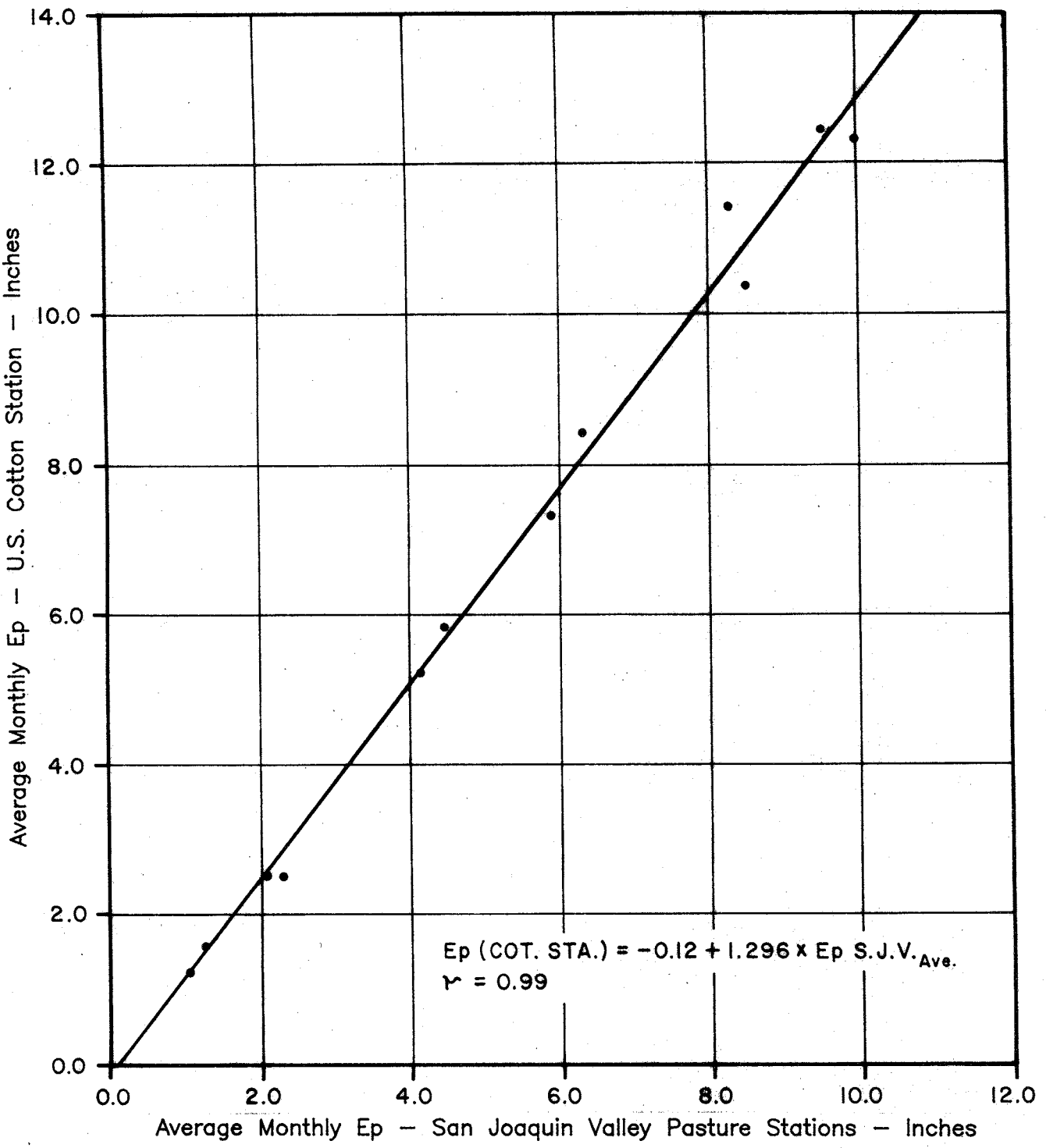


Figure 4. Relationship Between Average Monthly Evaporation from Class "A" Pans (Ep) at USDA Cotton Research Station [1] and San Joaquin Valley Irrigated Pasture Stations [2]

[1] Average evaporation 1965 to 1975.
[2] Average of 14 stations, from Appendix D, DWR Bul. 113–3.

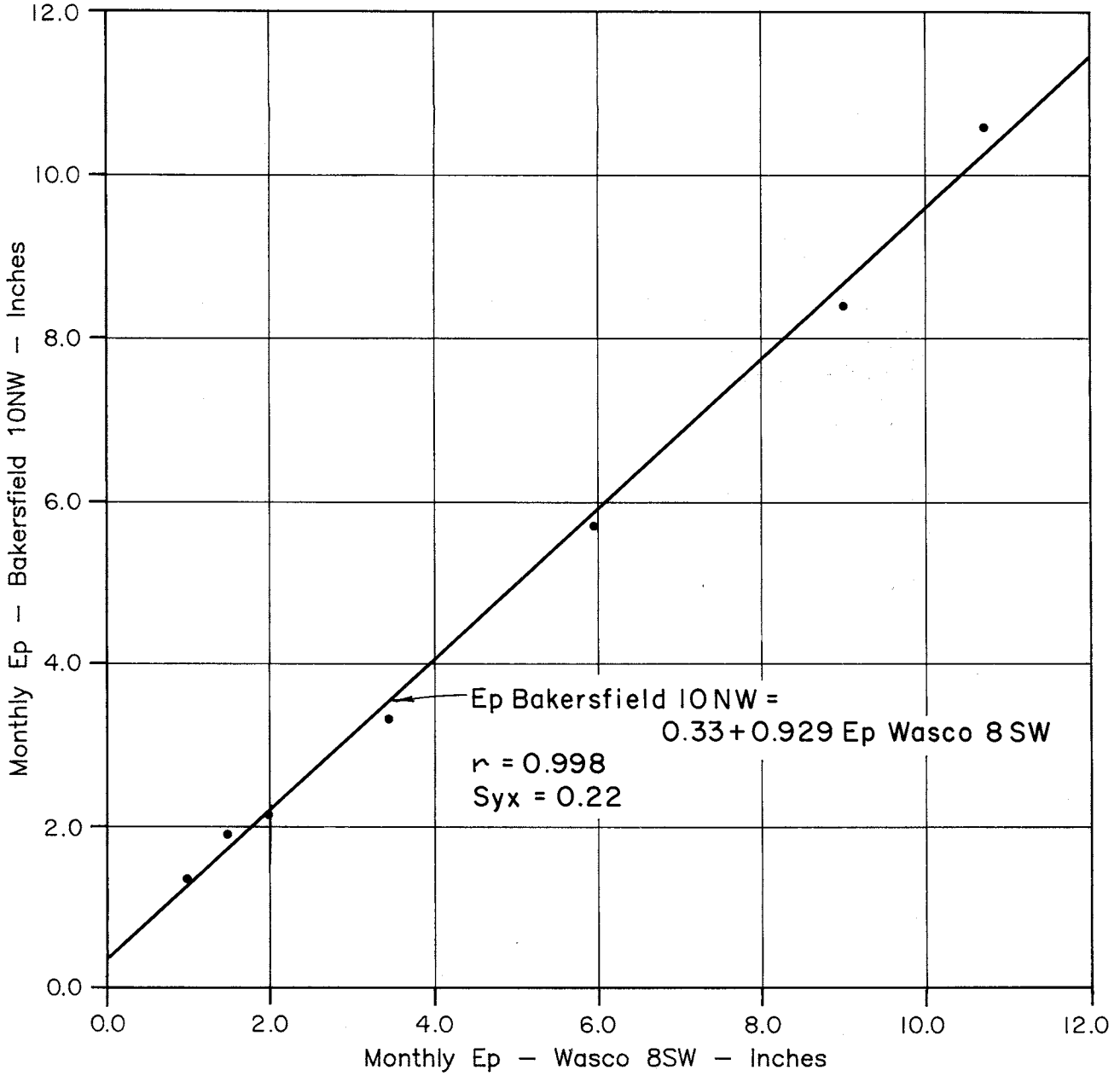
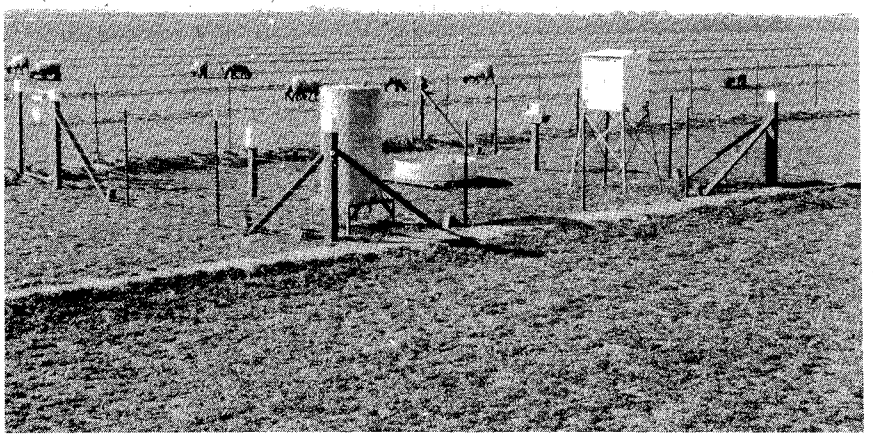


Figure 5. Relationship Between Observed Monthly Pan Evaporation (Ep) at Bakersfield 10NW and Wasco 8SW Agroclimatic Stations November 1980 to May 1981

Climate station at USDA Cotton Research Station, Shafter. Border strip in which instruments are located is planted to low-growing grass. Surrounding fields are planted to annual crops. Observations are made daily.



Wasco 8SW agroclimate station. Station is approximately 400 feet downwind from edge of pasture. Observations are made weekly.

Beginning January 1, 1981, DWR estimates of crop water use were based upon evaporation observed at Bakersfield 10NW. Data from that station were used until May 1990, when the record was shifted to the average of the Bakersfield 12S and Lamont 2NW agroclimatic stations (see Figure 1). The average of observed evaporation for those two locations continued to be used through 1991.

Corrections for Periods of High Evaporation

For periods of high wind or very high or low relative humidity, observed evaporation was corrected to compensate for the different response of plant transpiration and evaporation from the pan water surface. The correction factors used are listed below.

Evaporation Corrections[1]

Wind Movement Miles Per Day	Mean Relative Humidity – Percent		
	<40	40 – 70	>70
0 – 100	0.88	1.00	--
100 – 200	0.83	0.96	1.00
200 – 300	0.79	0.89	0.96

[1]Adapted from Table 19, United Nations Food and Agriculture Organization Irrigation and Drainage paper No. 24, *Crop Water Requirements*, United Nations, Rome, 1977, p 55.

It was necessary to use evaporation corrections only once or twice each year.

Calculated Crop Water Use

From January 1977 through December 1985, crop water use was calculated for each day (Figure 6). To estimate ET on a daily basis requires daily observations of evaporation. Since the cost of measuring evaporation each day at Wasco 8SW was prohibitive, the weekly evaporation at that station was prorated to daily amounts on the basis of daily records of evaporation observed at the USDA's Cotton Research Station.

In January 1986, the format for reporting current-year crop ET was changed. Rather than listing crop ET for each day of the previous week (7 values), average daily ET rates for the week were reported (1 value). This change was made because daily ET estimates usually did not vary greatly from day to day, or from the average daily rate over a weekly period.